EXHIBIT

3

DEFENDANTS' MOTION TO EXCLUDE THE TESTIMONY OF DR. CHRISTOPHER TEAF

05-CV-0329 GKF-PJC

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF OKLAHOMA

STATE OF OKLAHOMA, ex rel.)
W.A. DREW EDMONDSON, in his)
capacity as ATTORNEY GENERAL OF)
THE STATE OF OKLAHOMA and)
OKLAHOMA SECRETARY OF THE)
ENVIRONMENT C. MILES TOLBERT,)
in his capacity as the TRUSTEE FOR)
NATURAL RESOURCES FOR THE)
STATE OF OKLAHOMA)
)
Plaintiffs,)
)
vs.) Case No. 4:05-cv-00329-GKF-SAJ
)
1. TYSON FOODS, INC.,)
2. TYSON POULTRY, INC.,)
3. TYSON CHICKEN, INC.,)
4. COBB-VANTRESS, INC.,)
5. AVIAGEN, INC.,)
6. CAL-MAINE FOODS, INC.,)
7. CAL-MAINE FARMS, INC.,)
8. CARGILL, INC.,)
9. CARGILL TURKEY PRODUCTION, LLC.,)
10. GEORGE'S, INC.,)
11. GEORGE'S FARMS, INC.,)
12. PETERSON FARMS, INC.,)
13. SIMMONS FOODS, INC., and)
14. WILLOW BROOK FOODS, INC.,)
)
Defendants.)

EXPERT REPORT OF DR. CHRISTOPHER M. TEAF

Qualifications & Experience

1. My name is Dr. Christopher M. Teaf. I am over 18 years of age and am competent to testify. All opinions presented in this statement reflect personal knowledge based on information and data that I have reviewed in this case. All

opinions presented in this affidavit are given to a reasonable degree of scientific certainty.

2. My educational background includes a Bachelor's degree in Biology (with Honors) from Pennsylvania State University (1975), a Master's degree in Biological Science from Florida State University (1980), and a Ph.D. in Toxicology from the University of Arkansas for Medical Sciences (1985), where I conducted my research at the Division of Genetic Toxicology, National Center for Toxicological Research (Jefferson, Arkansas).

3. I presently hold positions as Associate Director at the Center for Biomedical & Toxicological Research and Waste Management at Florida State University (since 1983), as well as Director of Toxicology for Hazardous Substance & Waste Management Research, Inc. since 1985 (President since 1989). I have held adjunct teaching appointments at the Florida State University/State University System Program in Medical Sciences and the Florida A & M University College of Pharmacy and Pharmaceutical Sciences.

4. My ongoing research and scientific advisory interests principally are in the area of health risk assessment for human exposure to occupational and/or environmental chemical, physical and biological hazards. My principal activities for approximately 25 years have included the performance of risk assessments concerning human health and the evaluation of adverse effects of chemical, physical and biological exposures under the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, Superfund), Superfund Amendments and Reauthorization Act (SARA), the Resource Conservation and Recovery Act (RCRA), the Toxic Substances Control Act (TSCA), the Occupational Safety and Health Act (OSHA), and other related federal or state legislation. These professional activities over three decades have involved the evaluation of potential human health impacts of many organic substances (*e.g., petroleum products, pesticides, chlorinated and non-chlorinated chemicals*), as well as inorganic and/or physical agents (*e.g., acids/caustics, metals, particulates, fibers*), and

microbiota (*e.g., molds, fungi, bacteria*) in air, water, soils sediments and other environmental media.

5. For over two decades, I have served as a peer reviewer for publications submitted to numerous scientific journals, including Human & Ecological Risk Assessment, Environmental Forensics, Environmental Toxicology & Chemistry, Chemosphere, Bulletin of Marine Science, Ohio Journal of Science, Journal of Phytoremediation, and Environmental Biology of Fishes, as well as for reviews of research submitted to the Agency for Toxic Substances and Disease Registry (ATSDR) and the World Health Organization (WHO). I presently serve on the Editorial Boards for several of these scientific journals, and am the Senior Human Health Editor for Human & Ecological Risk Assessment, an international journal. I have published many scientific papers, articles and book chapters concerning toxicological effects and risk evaluations related to occupational and environmental exposures and effects. A complete copy of my Curriculum Vitae, including publications, is included as Attachment B to this report.

6. For approximately 25 years, I have directed and conducted research projects and human health education activities for agencies such as the World Health Organization (WHO), the North Atlantic Treaty Organization (NATO), the U.S. Environmental Protection Agency (U.S. EPA), the U.S. Department of Energy (U.S. DOE), the U.S. Department of Agriculture (U.S. DOA), the federal Agency for Toxic Substances and Disease Registry (ATSDR), the Florida Department of Environmental Protection (FDEP), the Florida Department of Health (FDOH), and the Florida Department of Community Affairs (FDCA).

7. I served as Toxicologist representative to the Toxic Substances Advisory Council for the Florida Department of Labor and Employment Security, the agency responsible for implementation of the Florida Right-to-Know Law, from 1990 to 2000, and I was Chair of that group from 1992 to 1996. I serve presently as a member of the Advisory Board of the Center for Terrorism and Public Health within the Florida State University College of Medicine. I served as toxicologist to the Florida Governor's Financial and

Technical Advisory Committee concerning petroleum site remediation issues from 1986-1992, and also as toxicologist representative to the Florida Landfill Technical Advisory Group (1994-1995) for FDEP. I presently serve as Toxicologist representative to the state Petroleum Technical Advisory Committee. In addition, for nearly 20 years I have been toxicologist representative, appointed by the Secretary of the FDCA, and have served for a period of time as Vice-Chairman of the District 2 Local Emergency Planning Committee under the State Hazardous Materials Emergency Response Commission. I was the appointed liaison for the State University System Toxicological Research Coordinating Committee and the (then) Florida Department of Environmental Regulation (FDER) from 1986-1989.

8. Since the late 1970's, I have organized and participated in many full length graduate and undergraduate level academic courses, multi-day technical training courses and seminars for organizations such as the NATO, the WHO, the American Bar Association, U.S. EPA, U.S. DOA, FDOH, Florida Engineering Society, Florida Hospital Association, FDEP, State Fire Marshal's Office, National Hazardous Materials Training Center, Florida State University, University of Florida, Florida A&M University, Georgia Institute of Technology, and the ATSDR. These technical courses and educational activities have included: issues of occupational/environmental chemical or biological exposures and public health (including toxicology and effects of occupational or environmental exposures), risk assessment, risk management, the implementation of health advisories for physicians, and ongoing health concerns regarding environmental contamination and occupational exposure situations in Eastern Europe (*e.g., Bulgaria, Czech Republic, Hungary, Poland*), in Central Asia (e.g., *Kazakhstan*), and in Russia. I have organized, coordinated and taught many 40 hour and 8 hour training courses on health and chemical safety issues related to OSHA requirements for the public and private sectors.

9. I have provided advisory services on toxicology, risk assessment, and health or environmental issues to the U.S. Attorney, the Florida State Attorney's Office and the Attorneys General for Florida, Washington, and Oklahoma. I have been qualified to provide expert testimony to federal and state courts, to administrative proceedings, and

to regulatory or legislative groups concerning toxicology, environmental chemistry, occupational exposures, human health effects of chemical substances, and health risk assessment since 1986.

Retention and Preparation

10. I have been retained in this case by the State of Oklahoma to provide technical analysis and opinions in the areas of toxicology and human health for issues associated with the land application of poultry waste within the Illinois River Watershed (IRW). Specifically, this report addresses health hazards related to bacteria and indicator organisms, to disinfection byproducts, including trihalomethanes (THMs) and haloacetic acids (HAA5s), and to cyanobacteria (also known as blue-green algae or BGA). In preparing my opinions in this case, I have reviewed many documents, reports, datasets, and scientific literature. Materials that I have reviewed are cited herein as appropriate or are included in my formal document production in this matter.

Impairments and Health Hazards in the Illinois River Watershed (IRW)

11. There are demonstrated historical and ongoing hazards and impairments associated with surface water and groundwater in the IRW. These include adverse conditions caused by "pathogens" (e.g., bacteria, viruses, and protozoa as included in the definition and application of the "indicator organisms" element of water quality criteria for Oklahoma and many other states), harmful blue-green algae (cyanobacteria), and chemical disinfection byproducts (i.e., trihalomethanes [THMs] and haloacetic acids [HAA5s]). The Illinois River and most of its tributaries, which include the Baron Fork and Flint Creek among others, historically have been classified by the State of Oklahoma as outstanding water resources for purposes of recreation, wildlife propagation and aesthetic values (OCC, 2004). These hazards and impairments that are present in numerous Illinois River Watershed streams demonstrate conditions that limit the designated uses of the water resources, and they represent an imminent and substantial endangerment to human health.

12. In 2003, the Oklahoma Secretary of the Environment issued a formal report stating that the general health and the water quality of the Illinois River were endangered by pollution from stormwater that runs off from poultry operations or from fields on which waste has been spread (OSE, 2003). Additionally, Engel (2008) developed an approximate poultry waste generation (tonnage) amount for each of the Defendants on a monthly basis, an annual basis, as well as the entire time frame of 1998-2006. His conclusions were that the vast majority of poultry waste generated inside the IRW is disposed inside the IRW, and that a significant amount of poultry waste generated outside of the IRW is disposed inside the IRW as well. Fisher (2008) has reviewed the geology and hydrology of the IRW and has concluded that the IRW is an area of high permeability and that groundwater is particularly susceptible to impact by surface contamination, including land-applied poultry waste. He also has provided estimates of the timing of poultry waste application during the year. Harwood (2008) has addressed a number of critical issues related to bacterial occurrence, origin and significance, concluding that poultry waste poses significant health issues for river users in addition to posing serious environmental problems for the entire IRW. Through various matrix samples, Harwood identified a unique bacterial biomarker which indicates that IRW contamination can be linked specifically to poultry operations and poultry waste land disposal practices.

13. Olsen (2008) has addressed a variety of chemistry and data collection issues to characterize impacts to the IRW, and has demonstrated by evaluating metals, nutrients, other analytes, physical measurements, and indicator organisms, a unique poultry-related chemical "signature". Through his analyses, he concluded that the "signature" has been and is present in environmental samples collected throughout the IRW. Olsen makes the additional distinction that the unique poultry "signature" in surface water is <u>not</u> found in the absence of poultry operations. In addition, statistical measures of common presence for a variety of analytes and microbiota (e.g., Principal Component Analysis or PCA) have been addressed by Olsen (2008). Those measures support a conclusion that the bacterial impacts are related to, and occur coincident with, land application of poultry waste, including manure and litter (CDM, 2008).

14. Cooke and Welch (2008) have reviewed extensive data from the IRW and from Lake Tenkiller, a drinking water reservoir and recreational resource, concluding that the production of algal biomass in Tenkiller Reservoir (also known as Lake Tenkiller and Tenkiller Ferry Lake) is significantly correlated with the changes in total phosphorous and that the mean eutrophic state has ranged from mild to very eutrophic in recent years. The eutrophic conditions have bred and continue to breed blue-green algae which, in addition to causing nuisance tastes, odors, and toxins in potable water, contribute to the production of potentially carcinogenic disinfection by-products during the treatment process of potable water supplies. Caneday (2008) has evaluated recreational usage of the Illinois River and its tributaries, and has provided estimates of users and temporal distribution of recreational activities during the year. Stevenson (2008) has evaluated nutrient concentrations in the IRW and determined the concentrations to be higher than many other regions, as well as being directly related to poultry house densities located in the watershed. He also concluded that nuisance algal biomass as well as modifications in aquatic species composition were related to poultry house densities, coupled with Total Phosphorous (TP) concentrations.

15. The following sections provide information which illustrates why the observed hazards and impairments can be and are harmful to human health, and how those hazards and impairments are linked to the process of land spreading of poultry waste in the Illinois River Watershed.

Bacteria

16. There are currently nine water bodies within the Oklahoma portion of the IRW that are identified by the Oklahoma Department of Environmental Quality (ODEQ) and listed on the 2006 U.S. EPA 303(d) list as "impaired" for the beneficial use defined as Primary Body Contact Recreation (PBCR; Table B1, Figure B1) as a result of bacteria and indicator organisms, including *E. coli*, enterococci, and/or the fecal coliforms (ODEQ, 2006a). It should be noted that one segment (OK 121700030080) of the Illinois River inadvertently was omitted from the 2006 Oklahoma U.S. EPA 303(d) list comprised of 8 segments, an oversight which subsequently has been corrected (ODEQ, 2008). That omission represented a 31.5-mile stretch on the main stem of the Illinois River where a

large amount of intensive aquatic recreational activity on the river takes place (Caneday, 2008). With the inclusion of that 31.5-mile segment, over 75% of the main stem of the Illinois River and its major tributaries is considered to be "impaired" for the category of "pathogens" (Figure B1), due to the presence of fecal indicator organisms, including bacteria.

17. The U.S. EPA 303(d) List is prepared on a biennial basis as an ongoing obligation under the 1972 amendments to the Clean Water Act and requires states to compile a list of water bodies that are "impaired" for various parameters, and to submit updated lists of the impaired water bodies to the U.S. EPA every two years (ODEQ, 2006a). The U.S. EPA 303(d) list defines an "impaired" water body as one which does not meet the state water quality standards, in this case the applicable standards are those related to Primary Body Contact Recreation with surface water. The presence and magnitude of microbial indicator organisms, as used in the context of impairment determinations, are commonly used and widely accepted measures of the potential for presence and health significance of pathogens, including bacteria, viruses and protozoa (Toranzos et al., 2002; WHO, 2003; NRC, 2004; EPA, 2005; Wade et al., 2006).

18. For the Oklahoma portion of the Illinois River's main stem and its major tributaries, approximately 77% is listed on the EPA's 2006 303(d) list. With respect to individual segments, the entire lengths (100%) of Sager, Tyner, Peacheater, and Flint Creek are designated as impaired. The Baron Fork is 66% impaired and Tahlequah Creek is 77% impaired (Figure B1). Caney Creek was taken off the 2006 303(d) list; however, water samples from the IRW segment, still show regular exceedances of indicator organisms, for which that water body failed several pathogen criteria in 2004 and 2002. It is important to note, however, that segments which are listed on the 303(d) impaired list, are not the only surface water sites within the IRW with exceedances of health-based water criteria. In addition, multiple detections of fecal indicator organisms have been found in Edge-of-Field samples, soils and sediments samples and other creeks/streams located in the IRW.

19. Throughout the Oklahoma portion of the IRW, land use designation primarily falls into one of two categories: forest or pasture (EPA, 2001a). Urban impacts are minimal in the Oklahoma portion of the watershed, with only three permitted National Pollutant Discharge Elimination System (NPDES) locations present, coupled with low human population densities in the Oklahoma portion of the IRW (EPA, 2007b). All three of these locations are present either far down on the Illinois River (i.e., Tahlequah) or they are located on downstream tributaries (e.g., Baron Fork and Caney Creek). Their impacts are further limited due to the relatively low permitted discharge rates, ranging from 0.28 to 5.27 million gallons per day (MGD; Table B3). Sewage bypasses and overflows are not significant sources of contamination under normal conditions. The Waste Water Treatment Plant's (WWTPs) in the IRW are all separate sewage systems (SSS's) which do not combine untreated waste with stormwater runoff, thus should not be as heavily impacted by large rain events as a combined sewage system (CSS) would be. Finally, the permitted bacterial limits are restrictive, thus controlling the total amount of bacteria that can be released from the systems.

20. Contamination of surface water and groundwater supplies by bacteria has long been recognized as a human health concern in the United States and around the world. The 1986 U.S. EPA *Ambient Water Quality Criteria for Bacteria* provided historical context and recommendations concerning appropriate guidelines for microorganisms (U.S. EPA, 1986). Subsequent refinements and updates to that guidance are represented by the *Implementation Guidance for Ambient Water Quality Criteria for Bacteria* (U.S. EPA, 2003). This health-based guidance fits into the operable "fishable/swimmable" goals of the Clean Water Act, which specifically requires that water quality standards must "protect the public health and welfare, enhance the quality of water, and serve the purposes of this Act."

21. Microbiological contamination of water can be caused by bacteria, viruses, protozoa and other related organisms. The number and diversity of these potential contaminants has resulted in the development of practical assessment and protection strategies which employ "indicator organisms" as a surrogate for the quantification of specific species in water bodies (Barrell et al., 2000; U.S. EPA, 2003; National Research

Council, 2004). These indicator organisms, such as *Escherichia coli* (*E. coli*), enterococci, and fecal coliform bacteria, may not cause illness directly, but they have demonstrated characteristics which make them reliable indicators of other harmful pathogens in water (Wade, 2006). Although the most commonly reported illnesses associated with bathing in contaminated water typically are gastrointestinal in nature, other illnesses and conditions affecting the eyes, ears, skin and upper respiratory tract can occur as well. Essentially all local, state, and national health agencies employ one or more of the indicator organisms in their water quality management programs, and this is true internationally as well (WHO, 2000; EPA, 2003). Thus, there is consensus that the presence of these indicator organisms at levels greater than the health-based criteria or standards represents a human health threat.

22. The 2003 U.S. EPA *Implementation Guidance* cited previously, provided detailed information regarding the basis for the environment and health agency recommendations, including discussions on the epidemiology of microbiological disease related to water uses such as swimming, kayaking, water skiing, and other activities where direct contact and immersion in the water are likely. For *E. coli*, a geometric mean density of 126 organisms per 100 milliliters (ml) of water over a 30-day period was associated with an illness rate of 0.8%, or 8 illnesses per 1,000 recreational users. As a short-term measure, this 0.8% illness rate was associated with bacterial counts of 236 per 100 ml as an upper limit. For the enterococci, a geometric mean of 33 organisms per 100 ml and an upper limit of 62 organisms per 100 ml were associated with the 0.8% illness rate (OAC, 2007). Above these threshold levels, the agency noted that illness rates rise sharply, and the health-based recommendation seeks to remain below that part of the statistical curve (Figure B2). The State of Oklahoma, along with many other states, has adopted these indicator organism criteria as a fundamental element of their water quality criteria for protection of human health.

23. The exposures represented by recreational uses of the Illinois River and its tributaries, as described by Caneday (2008), both floating and non-floating, are consistent with the types of activities considered by the EPA (2003) in its estimates of illness rates of 8 per 1000 people (0.8%) for indicator organisms in fresh water. Using

the figures for intensive uses of the Illinois River Watershed provided by Caneday (2008), it is possible to estimate that over 1,200 illnesses are occurring on an annual basis even if the bacterial water quality is just being met. While states can determine their own disease incidence targets, the EPA (2003) recommends less than 1.0% illness rate (e.g., 0.8% is used by many states). This is in part because the epidemiological data illustrate an exponential increase in rates beyond the 1.0% illness incidence threshold, instead of a linear increase. Stated differently, at low indicator organism densities (i.e. below the health-based recommendation) the pattern of increase in illness is fairly small and the line is flat, while at higher indicator organisms densities, the illness rate curve rises much more steeply (Figure B2).

24. Primary Body Contact Recreation (PBCR) is an exposure category defined by the State of Oklahoma Administrative Code in Title 785, Chapter 45 (OAC, 2007). This beneficial use category is specifically intended to protect recreational users of water bodies from contamination during the recreational season of May 1 through September 30. PBCR is defined as involving direct body contact (i.e., the dermal exposure route) with surface water through activities such as swimming, wading, canoeing, and fishing. It should be noted that PBCR also explicitly includes the additional likelihood of incidental water ingestion (i.e., oral exposure route) while recreation is occurring in the watershed through multiple activities (OAC, 2007). In water bodies that are governed by the PBCR requirements, the State of Oklahoma mandates that such water "shall not contain chemical, physical or biological substances in concentrations that are irritating to skin or sense organs or are toxic or cause illness upon ingestion by human beings" (OAC, 2007). Clearly, levels of bacteria and indicator organisms that exceed health-based criteria and other standards will and do pose such an unacceptable health risk to users of the Illinois River and its tributaries.

25. Information that is available regarding land disposal of poultry waste shows that nearly two-thirds (over 63%) of waste spreading occurs in the months of February through June (Figure B3), based upon data for the period 1999-2004 (Fisher, 2008; Engel, 2008). Information available regarding the pattern of a major PBCR use ("floating") within the Illinois River and its tributaries in the 2004-2007 period by month shows that

99% of that usage type occurs in the months of May through September (Caneday, 2008; Figure B3). Floating includes ancillary direct contact activities in the water such as swimming and wading as well, and reasonably can be considered to include an ingestion component of exposure, as well as dermal. Thus, a very large proportion of total annual land spreading of poultry waste is conducted during the months which just precede or overlap with the times of maximum direct contact recreational use of the Illinois River and its tributaries. Coincidentally, the rainy season in Oklahoma tends to be between February and June (NOAA, 2000), which coincides with and immediately follows the highest rates of waste application (Adamski, 1987; Adamski & Steele, 1988; Fisher, 2008). The rainy season also immediately precedes the highest rates of floating activity (Figure B4). On average, approximately 45% of annual rainfall in Northeast Oklahoma occurs between the months of February and June (NOAA, 2000). Rainfall, specifically when it occurs shortly after land spreading, results in microbial pathogen distribution as a result of runoff from spread poultry waste or by leaching through the soil profile (Giddens and Barnett, 1980; Gagliardi and Karns, 2000; Fisher, 2008; Olsen, 2008), even if buffer zones are used correctly, which they frequently are not.

26. Recently, over six consecutive years (2000-2005), there has been widespread measurement of the presence of indicator organisms in surface waters of the IRW, which indicate that those waters broadly and regularly exceed the Oklahoma Water Quality Standards and/or health-based screening levels (OWRB, 2007; CDM, 2008). Single point criteria for surface water along the impaired water body segments from recreational seasons 2005-2007 were exceeded in a large number of samples. Most of these samples are at least twice the standard and the values may exhibit exceedances up to a maximum of 125 times the standard (Table B2). Another example of regular and widespread exceedances of particular interest exist in specifically identified public access (PA) locations (Figure B5), most of which are within impaired water body segments, where a remarkable 13 of 15 locations (nearly 90%) had results where one or more indicators were in excess of the Oklahoma standards for fecal bacteria as shown by indicator organisms (CDM, 2008). In addition to single point criteria, a number of multi-sample geometric means within impaired water body segments, according to the

procedures of the Oklahoma Water Resources Board, also showed exceedances. The State of Oklahoma mandates that a geometric mean calculation for Primary Body Contact Recreation have no less than five samples for any 30-day time frame of interest (OAC, 2007). Results for the recreational seasons of 2005-2007 show exceedances in all water bodies where sufficient samples were taken to perform the calculation, with those exceedances being in the range of 2 to 30 times the standard (Table B2). While Peacheater Creek, Tyner Creek, Tahlequah Creek, and a portion of the Illinois River did not have adequate sampling frequency within the specified time frame to fairly calculate the geometric mean, the percentage of single point criterion exceeding the standard was in most cases nearly 20% of the samples, at levels that were 2 to 65 times greater than the health-based screening level (CDM, 2008; Table B2). These results, in my opinion, demonstrate a chronic and persistent problem of bacterial contamination which represents an imminent and substantial endangerment.

27. In addition to Primary Body Contact Recreation uses associated with surface water exposures, significant exposures to contaminated groundwater can occur through drinking water supplies as well. In Oklahoma, groundwater is protected such that bacterial levels in groundwater must be "nondetect", which is reasonable based on the absence of normal bacterial fauna in groundwater at deeper depths (NRC, 2004; EPA, 2006A; USGS, 2007b). Once groundwater pollution has been determined to have occurred via human activities, the water supply is to be restored to a quality sufficient to support its designated beneficial use, in this case potable water supplies (OAC, 2007). Over 1,700 groundwater wells have been identified in the Oklahoma portion of the IRW, of which 98% are used for domestic purposes (OWRB, 2008; Fisher, 2008; Figure B6). Figure B7 illustrates the CDM groundwater well sampling sites within the IRW while Figure B8 shows the locations of Geoprobe samples taken within the IRW. Bacterial contamination of groundwater, including impacts by *E. coli*, fecal coliforms and enterococci, has been demonstrated in many shallow wells and in other wells at depths to approximately 150 feet, as well as in a majority of shallow groundwater Geoprobe samples (CDM, 2008). Olsen (2008) identified the poultry "signature" in the majority of these samples. While these Geoprobe samples are not necessarily

completed to depths from which groundwater is taken for domestic purposes, they clearly demonstrate the potential pathway between microorganisms at the surface and those which can contaminate groundwater. These elements further demonstrate the vulnerability of shallow groundwater (NRC, 2004; Fisher, 2008), and illustrate the health concerns that are associated with land spreading of poultry waste in areas where groundwater is used for potable and other domestic purposes.

28. Bacterial levels of human health significance also have been found in a number of springs within the IRW. At their point of release from the ground, where they "daylight", springs represent a transition from groundwater to surface water. Thus, they can be indicators of impacts to groundwater and/or surface water (Fisher, 2008). Springs sampled in the Oklahoma portion of the IRW are shown in Figure B9. Approximately 21% of the spring samples exceeded the surface water bacterial standards. Most of those samples were located in close proximity to the Illinois River and its tributaries. Olsen (2008) concluded that nearly 40% of spring samples were impacted by poultry waste.

29. Bacteria have been detected in surface water, groundwater and springs in the IRW at levels that are indicative of significant concern from a human health perspective (CDM, 2008). Edge-of-Field samples for fields that have received recent spreading of poultry waste have shown bacterial colony counts in water which are similar to those reported for water samples into which, raw, untreated sewage (i.e., 10^5 or 100,000 MPN or greater) has been spilled from U.S. sewage treatment plants (Metcalf & Eddy, 1991; Brosnan et al., 1996; CDM, 2008; Harwood et al., 2005). Of the 22 Edge-of-Field sample locations which exhibited bacteria and indicator organism results in excess of 100,000 MPN per 100 milliliters, seven of the locations exhibited results for enterococci, fecal coliforms and/or total coliforms greater than or equal to 1,200,000 MPN per 100 milliliters, with three sites having a total of 5 reports of greater than or equal to 1,600,000 MPN per 100 milliliters (Table B6). Through Principal Component Analysis (PCA), it has been determined that 100% of the Edge-of-Field samples showed poultry related impacts. Furthermore, of the 50 highest "PC1" (poultry) scores of all sampled media, 44 were Edge-of-Field samples, with the highest score resulting in a sample

taken from field runoff immediately after poultry waste application (Olsen, 2008). In addition, the maximum levels for *E. coli*, enterococci and fecal coliform found in poultry litter/waste samples collected by CDM in 2006 were 120,000 MPN per gram of litter (CDM, 2008). Other impacted media include sediments and soils as demonstrated by Fisher (2008) and Olsen (2008).

30. In addition to the numerical comparisons between health-based criteria and detected levels of bacteria and indicator organisms as a measure of potential health hazard, it is useful to consider the relative importance of microbial sources in the IRW as well. Processes to accomplish this have been developed by USEPA and a number of individual states, including Oklahoma, under the Total Maximum Daily Load (TMDL) program (USEPA, 1997; USEPA, 2001b; ODEQ, undated).

31. An analysis of potential sources for fecal coliforms was conducted in a fashion consistent with that employed by USEPA and ODEQ for the six counties which share some portion of the Illinois River Watershed (Adair, Cherokee, Delaware and Sequoyah in OK; Benton, Washington in AR). That analysis considered fecal coliform contributions by a variety of categories for which data were available, including: domestic pets, deer/wildlife, failing septic systems, permitted point sources (i.e., NPDES outfalls), and livestock. The livestock category was further subdivided into groups by poultry, cattle/calves, horses/ponies, sheep/lambs, and swine. Table B4 summarizes the contributions for each source category, and also provides a summary of the relative contribution from the five livestock categories. The numerical values for each category are expressed in units of Colony Forming Units per day (CFU/day). For example, the total fecal coliform load from poultry and from cattle/calves is approximately 5×10^{15} CFU/day, or 5,000 trillion CFU/day each. Table B5 provides the underlying summary calculations and input parameters for the values presented on Table B4.

32. Several important conclusions can be drawn from this source contribution analysis, including the following:

- The categories of domestic pets, deer/wildlife, failing septic systems and point sources each contribute from 0.01% to 0.9% of total fecal coliform loading. Those contributions are not significant in comparison to the contribution from livestock;
- The livestock category alone contributes nearly 99% of total fecal coliform loading;
- Within the livestock category, poultry and cattle/calves each contribute just over 40% each of the total, swine contribute about 14% of the total, sheep/lambs contribute about 0.1% of the total, and horses/ponies contribute about 0.03% of total fecal coliform loading;

In addition, leachability of poultry waste was on the order of 1 to 5 times higher than fresh cattle manure, and is likely to be even greater for dry manure based on the smaller particle sizes present in poultry waste (Olsen, 2008). Therefore, poultry waste is much more likely to leach components with the potential for adverse impacts from the site of application to nearby water sources, than is cattle manure.

33. For over a decade, the practice of adding antibiotics (e.g., fluoroquinolones, tetracyclines, aminoglycosides, macrolides) to farm feed has been widely used to fight microbial infection in poultry and other livestock, as well as sub-therapeutically to increase feed conversion efficiency and weight gain (Nandi et al., 2004; PCIFAP, 2008). Concern has been raised about the ability of bacteria such as *E. coli*, *Salmonella*, *Campylobacter*, and *Staphylococcus*, which are common in poultry, to become antibiotic-resistant, thereby representing a source of infection in humans as a result of this widespread antibiotic use in farming (White et al., 2003; USFDA, 2002; Nandi et al., 2004; Hurd et al, 2004; Diarra et al., 2007; Dupont, 2007; Smith et al., 2007; PCIFAP, 2008). Price et al. (2007) reported that individuals who work in the poultry industry were much more likely to carry antibiotic resistant strains of *E. coli* than other members of the community. According to the World Health Organization, the "use of antimicrobials outside of human use is of serious concern given the alarming emergence of bacteria, which have acquired, through this use, resistance to antimicrobials" (WHO, 2008a). These concerns ultimately led the European Community to prohibit the use of antibiotics as growth promoters. Antibiotics used by the poultry industry, including defendants in this case, to treat or control bacterial diseases include: Baytril

(enrofloxacin), Sarafloxacin, Bacitracin (BMD), Penicillin (e.g., Ampicillin, Amoxicillin, Methicillin), Gentamycin sulfate, and tetracyclines (e.g., chlortetracycline (CTC), neo-terramycin, oxytetracycline), among others (see e.g., Bates #: TSN088218SOK, TSN088077SOK, TSN088197SOK, CM003570, SIM AG09496, CARTP109186). In addition to antibiotics, pesticides (e.g., Larvadex, Fenbendazole, Piperazine, Levamasol) are also added to feed to control worms and fly larvae (see e.g., Bates #: CM003473, CARTP169958, CARTP143292, CARTP158787), and thus would be present in excreted poultry waste. This information clearly illustrates that a number of significant pathogens are a recognized and inherent health concern associated with poultry raising operations, and that the industry historically has actively treated the flocks to control these very bacteria in poultry waste which are potentially dangerous to the flocks.

34. It is evident that the poultry industry is and has been aware for some time of the potential health problems that these pathogens represent due to the widespread use of the veterinary antibiotics (see previous paragraph). Before the use of fluoroquinolones became common in animal husbandry (including poultry), antibiotic-resistant bacterial strains were virtually nonexistent (Bren, 2001; WHO, 2008b). In reference to the benefit of fluoroquinolone use being compromised, Hofacre et al. (1999) noted that the "Use of antibiotics in both humans and animals contributes to the selection pressure resulting in this resistance". *Campylobacter* from 28% of human patients in one study showed resistance to fluoroquinolones (Ellis-Pegler et al., 1995). In one particular case, *Salmonella minnesota* and *E. coli,* isolated from a number of turkey poults, were subjected to an antibiotic susceptibility pattern test. In that analysis, *E. coli* showed resistance to 13 of the 16 antibiotics tested and *S. minnesota* showed resistance to 10 of the 16 antibiotics tested (University of Missouri Veterinary Lab, 2007). It appears that the turkeys in question must have been subjected to numerous antibiotics in feeding operations, judging by their resistance to such a broad list of antibiotics. However, this particular case simply further illustrates what White et al. (2000) previously had demonstrated: that antibiotic-resistance is and has been on the rise. *Campylobacter* have been shown elsewhere to be broadly resistant to macrolide antibiotics (Bolenger and Shryock, 2007). In their study, White et al. (2000) showed avian (poultry) pathogenic *E.*

coli (APEC) resistance to Sarafloxacin increased from 15% in 1996 to 40% in 1999 and dual-resistance to Sarafloxacin and to Enrofloxacin increased from 9% in 1997 to 30% in 1999. To further illustrate the growth of multi-antibiotic resistance over time, three separate studies performed by Bass et al. (1999), White et al. (2000), and Zhao et al. (2005) published APEC results of 64%, 66%, and 71% of samples, respectively, having resistance to five or more antibiotics. With respect to individual antibiotics, the same three studies demonstrated that the use of tetracyclines has become so extensive that APEC-resistant strains ranged from 85 to 89% of bacteria, while Gentamycin resistance is in the range of 62 to 69% of APEC strains. Therefore, the spreading of poultry waste material clearly aids in the dispersion of antibiotic resistance in the environment, creating imminent and substantial endangerment to those using the river, as well as contributing to this recognized worldwide problem of antibiotic resistance.

35. Land spreading of poultry waste has long been recognized as a major bacterial contamination source (Crane et al., 1980; Adamski, 1987; Adamski and Steele, 1988; PCIFAP, 2008). Spreading of waste material, a traditional agricultural waste disposal practice, becomes a major source of contamination because frequently it exceeds the rate at which wastes can be accommodated by or processed in agricultural ecosystems (Coyne and Blevins, 1995). Rainfall, specifically when it occurs shortly after land spreading, may then result in pathogen distribution by runoff from spread poultry waste or by leaching through the soil profile (Giddens and Barnett, 1980; Gagliardi and Karns, 2000; Fisher, 2008; Olsen, 2008), even if buffer zones are used correctly, which they frequently are not. This is rendered even more important by the fact that the recreational season for the IRW overlaps with and immediately follows the rainy season, a period which is well within the survivability duration of the bacteria in question (Figure B4). Furthermore, the leachability of poultry waste components into groundwater significantly outweighs that of cow manure (Olsen, 2008). The environmental survivability of bacteria can be on the order of several days to many months (Jamieson et. al., 2002; Tetra Tech, 2004; Davis et al. 2005). Runoff from waste-spread fields carries excess nutrients, pollutants, and pathogens to nearby waterways, which negatively affects surface water, groundwater, aquatic life, and human health;

even months after land application of waste, fecal coliforms and *E. coli* can be resuspended from sediments and transported downstream (Coyne and Blevins, 1995; Hartel et al., 2000; Davis et al., 2005; Ringbauer et al., 2006).

36. Bacteria of human health significance, including *Campylobacter, Salmonella, Staphylococcus*, *Escherichia coli* and other important species, as well as bacterial indicator organisms such as fecal coliforms and enterococci, are present in poultry waste (Kelley et al., 1995; Jenkins et al., 2006; CDM, 2008; PCIFAP, 2008). The presence of microbial indicator organisms in surface and groundwater bodies suggests that other dangerous bacteria such as *Campylobacter*, *Salmonella* and/or *Staphylococcus* also may be present, in addition to ancillary viruses and protozoa that are more difficult to monitor (e.g., Cryptosporidium).

37. *Campylobacter* is a common intestinal bacterium found in a wide range of poultry, domestic livestock, and wildlife (Neill et al., 1984; Lindblom et al., 1986; Kazwala et al., 1990; Waage et al., 1999; Chen et al., 2006; Doyle and Erickson, 2006), though it is quite commonly associated with poultry operations and products globally (Hald et al., 2007), and it is more prevalent in poultry than in swine or cattle (Belanger and Shryock, 2007). While often referred to primarily as a foodborne illness, *Campylobacter* may be waterborne as well (Allos, 2001; O'Reilly et al., 2007). The major effects and complications of *Campylobacter* infection can occur in or near the gastrointestinal tract (USDA, 1991; Allos, 2001; Murray et al., 2003); however enteric (intestinal) diseases are not the only cause for concern. Human campylobacteriosis frequently presents as a sporadic infection, such that it is common to find individual cases in contrast to related outbreaks affecting a large group (Friedman et al., 2000). This sporadic occurrence pattern and the frequently self-limiting nature of the infection causes campylobacteriosis, as well as other enteric diseases that are transmitted by the waterborne route, often to be underreported to public health agencies (Belanger and Shryock, 2007; Leclerc, 2002). Even when diagnosed, campylobacteriosis is reported infrequently (Allos, 2001), and Mead et al. (1999) concluded that less that 3% of diagnosed *Campylobacter* gastroenteritis cases are reported to health authorities.

38. *Salmonella* sp. are bacteria also frequently associated with poultry (Barbour and Nabbut, 1981; Jacobs-Reitsma et al., 1994; Himathongkham et al., 1999; Doyle and Erickson, 2006; Li et al., 2007), and numerous *Staphylococcus* species have been isolated from chickens, including *S. aureus, S. sciuri, S. gallinarum, S. lentus, S. chnii, S. xylosus,* and *S. warneri* (Adegoke, 1986; Terzich et al., 2000). Infectious diseases related to fecal bacteria from poultry waste include campylobacteriosis, giardiasis, cryptosporidiosis, salmonellosis, *E. coli* 0157:H7, and others (Doyle and Schoeni, 1987; Leclerc et al., 2002; Dipineto et al, 2006; Doane et al., 2007; Dupont, 2007; OSDOH, 2007; Trampel et al., 2007). The State has recognized the potential impacts of chicken waste under such acts as the Oklahoma Confined Animal Feeding Operation and Poultry Registration Acts (ODAFF, 2008). Recognition of human disease acquired by animal sources by the Experts Scientific Workshop has resulted in placing the highest priority for further research on contamination from poultry and other agricultural animals (U.S. EPA, 2007c). Gastroenteritis, caused by fecal pathogens and characterized by nausea, cramps, diarrhea, and vomiting, is a common and serious affliction associated with waterborne bacteria (OSDOH, 2007; VGHI, 2007). Following the review of 22 articles, Pruss (1998) concluded there to be a causal relationship between gastroenteritis and recreational water quality, as measured by bacterial indicators. Important infections caused by *Staphylococcus*, including recent antibiotic resistant strains (e.g., Methicillin-resistant *Staphylococcus aureus*, MRSA), involve skin, and may result in boils, cellulitis, impetigo and serious wound infections. Many other organ systems in the human body can be affected as well (Kloos and Bannerman, 1999; Murray et al., 2003). Strains of *Salmonella* and other bacteria have undergone adaptations to become antibiotic resistant, as described previously in the report.

39. The Oklahoma State Department of Health (ODOH) maintains statistics of specific reportable diseases including diseases caused by bacteria such as *Campylobacter*, *Salmonella*, and *E. coli* 0157:H7, and microscopic parasites such as *Giardia* and *Cryptosporidium*. As described elsewhere in this report, these organisms have been associated with poultry waste and often are also associated with contaminated drinking water, fecal material, and contact with birds. An evaluation of OSDOH records for

Oklahoma counties in the IRW shows that Adair County reported rates of campylobacteriosis considerably in excess of the state average for the period 1997 to 2005 (ODOH, 2006; see Figure B10). Adair County makes up the largest portion of land area within the IRW. In addition, rates of salmonellosis reported between 1990-2005 also have periodically exceeded the average statewide incidence rate. The rate of salmonellosis in Sequoyah County was reported to exceed the state rate for all except three years during the period 1990 to 2001 (ODOH, 2006; see Figure B11). Furthermore, the data from the ODOH shows no associations between serotypes of the *Salmonella* bacterium. In addition to the lack of commonality between serotypes, no common relationships between individuals, demographic characteristics, or locations were identified, as would be expected from a single, large food-borne outbreak (ODOH, 2006).

40. While the ODOH has not investigated any "outbreaks" with regard to the diseases discussed above, it cannot be presumed that incidents of infection are not occurring. Without question, tourism within the watershed is extensive, considering for example, that the general population of Adair County during the period 1990 to 2000 ranged from about 19,000 to 21,000 people (U.S. Census, 1990; U.S. Census, 2000) and at least an estimated 155,000 people use the IRW annually (Caneday, 2008). When using the CDC's guidelines for investigating an outbreak, a clustering of sickness must take place to warrant an investigation. This, therefore, would be very difficult to achieve under recreational use circumstances, recognizing how many tourists visit the Illinois River watershed from Arkansas, Kansas, Missouri, as well as other counties in Oklahoma. Lee et al. (2002) noted that outbreak investigations were increasingly difficult to document when users convene onto one venue and then geographically disperse. This clearly identifies one possible reason why no focused investigations have been initiated for the Illinois River Watershed. Latency periods in the order of a day to a week (Mayo Clinic, 2008; CDC, 2008), depending on the bacterium, would surely affect reporting statistics if recreational users and tourists to the region are taken into account, and consideration is given to the likelihood of returning to their homes after visiting the IRW. Additionally, outbreaks associated with some infective organisms are

less likely to be investigated than acute diseases characterized by short incubation periods, serious illness requiring medical treatment, and those having recognized etiologies (Lee et al., 2002; Blackburn et al., 2004). Individual sensitivity and enhanced susceptibility among groups such as children, the elderly, and the immuno-compromised, further complicates the effectiveness and applicability of disease surveillance (WHO, 2003; NRC, 2004).

41. It is clear that many diseases are commonly under-reported, given the limitations of the passive disease surveillance systems presently in place. Multiple factors play a role in whether disease outbreaks are recognized, investigated, and/or reported, which typically will result in under-reporting of the true illness rate (Lee et al., 2002; Blackburn et al., 2004; Liang et al., 2006; Craun & Calderon, 2006;). Multiple studies (Lee et al., 2002; Yoder et al., 2004; Blackburn et al., 2004; Liang et al., 2006) have concluded that the data which are collected most commonly pertain to "outbreaks," with no mechanism to include seemingly sporadic cases, and therefore the data do not necessarily represent actual endemic trends with waterborne illnesses. The observations already available concerning disease occurrence in northeastern Oklahoma underscore the potential for increases in infectious diseases related to land disposal of poultry waste in large quantities.

42. The bacterial impacts associated with the application of poultry waste to lands in the Illinois River Watershed represent an imminent and substantial endangerment to human health.

Trihalomethanes (THMs) and Haloacetic Acids (HAA5s)

43. One human health risk associated with the spreading of poultry waste on agricultural fields in large quantities, with associated runoff, is related to the formation of potentially carcinogenic substances that may occur in treated drinking water supplies (Cooke and Welch, 2008). Formation of these products can occur during the normal municipal treatment of water prior to distribution, and is a result of increased organic matter in the raw intake water which combines with chlorine to form "disinfection byproducts" (DBP's). Several examples of which are trihalomethanes (THMs) and

haloacetic acids (HAA5s). One direct and/or indirect source of this increased organic matter is contaminated runoff from fields on which poultry waste have been spread. Studies have shown there to be an increase in the poultry population and thus an increase in the amount of waste generated by poultry dating back as far as 1950 (Engel, 2008; Fisher, 2008). The total amount of waste generated annually within the IRW was estimated to be over 300,000 tons (Fisher, 2008). Increased organic matter, in conjunction with excessive nutrients, primarily nitrogen and phosphorus, from poultry waste are principal recognized causes of eutrophication, algal growth, and water quality degradation (Lee and Jones, 1991; Cooke and Welch, 2008; PEW, 2008). This scenario is illustrated in Figure T1. The principal source of phosphorus to Lake Tenkiller has been attributed to poultry waste applied to pastures that eventually reaches the Illinois River and then Lake Tenkiller (Engel, 2008; Cooke and Welch, 2008). One of the most effective methods to control eutrophication and restore water quality is by reducing the excessive phosphorus sources (Sas et al., 1989; Lee and Jones, 1991; Slaton et al., 2004; Cooke and Welch, 2008), which in this case could be accomplished by decreasing or eliminating the contribution made by poultry waste.

44. Nutrient pollution to surface waters from "insufficiently treated sewage, runoff from fertilized agricultural areas and lawns, manure and more complex effluent from livestock industries" (Briand et al., 2003), can and does result in eutrophication and algal proliferation. The increase in these algal communities, including those of cyanobacteria, disrupt the complex aquatic environment within the system, which can lead to oxygen depletion, taste and odor issues, and the formation of organics in the water (Fruh, 1967; Hoehn et al., 1980; van Steenderen et al., 1988; Cooke and Welch, 2008; Stevenson, 2008). Cyanobacteria, such as *Microcystis aeruginosa*, have been shown to be productive precursors of trihalomethane disinfection byproducts in treated water supplies (van Steenderen et al., 1988).

45. Chlorine treatment, which has been the most widely used and cost effective disinfectant practice for U.S. public or private water supplies since the early-1900's and which is commonly used in wastewater treatment facilities (NAS, 1987; Bull et al., 1995), may result in the formation of chemicals known as DBPs, which are of ongoing health

concern (Wistrom et al., 1996; USEPA, 2006c). These DBPs include the predominant class of trihalomethanes, or THMs (consisting of chloroform, bromodichloromethane, dibromochloromethane, bromoform), as well as the haloacetic acids, or HAA5s, (consisting of monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid). In addition to these groups, other disinfection byproducts are continually being evaluated for occurrence, toxicity and potential human health risk (Krasner et al., 2006). The formation of DBPs in treated water is a well-recognized phenomenon, and depends on factors such as pH, nature/concentration of organic matter, chlorination contact time, water temperature, chlorine dose, chlorine residual, and bromide concentration (Stevens et al., 1976; Reckhow and Singer, 1990; OWRB, 2005; USEPA, 2006b; Gopal, 2007; Cooke and Welch, 2008).

46. The formation of DBPs is correlated significantly with the content of dissolved organics in raw water (Martin et al., 1993; Stepczuk et al., 1998; Stuart et al., 1999; Gallard and Gunten, 2002; Brown, 2003). Under normal circumstances, naturally occurring organic material (NOM) is a principal precursor with which halogens (e.g., chlorine and bromine) can react to form DBPs (Rook, 1976; Oliver and Lawrence, 1979; Marhaba and Kochar, 2000; Gopal et al., 2007; Richardson et al., 2007; Wang et al., 2007). However, nutrient enrichment (e.g., loading of phosphorus, Total Organic Carbon (TOC), and nitrogen) in water bodies from activities such as spreading of poultry waste to pasture lands, can increase organic matter concentrations and dramatically increase or speed up eutrophication processes in lakes, often with accompanying increases in algal growth, which also can result in increased DBPs (Peterson et al., 1993; Preusch et al., 2002; Lee et al., 2007; Cooke and Welch, 2008). Water samples taken directly following waste application and right after rainfall (Edge-of-Field) from the IRW show high levels of TOC.

47. Excess nutrient loading and nutrient pollution in some circumstances can originate from urban runoff, industry, automobiles, and human sewage. However, in many areas the largest source comes from agriculture and from uses of manure produced by livestock, including poultry, on fields (Anderson et al., 2002; Tang et al.,

2005). Engel (2008) concluded that excess amounts of these fertilizer constituents, in the form of manure and litter spread in quantities beyond that which can be sequestered by plants and soil, lead to increased amounts of phosphorus in runoff. In addition, Engel (2008) concluded that close to 80% of the net annual phosphorus contribution to the IRW comes from poultry. High levels of phosphorus in runoff act to fertilize the aquatic life in water, leading to excessive growth of algae and underwater plants that can lead to production of DBP's (Hoehn et al., 1980; Dore et al., 1982; Lee and Jones, 1991). Enhanced nutrient loading can also increase the formation of *Cladophora*, a branching filamentous green alga, often times found on rocky substances. Stevenson (2008) showed that the algal biomass density was related to total phosphorus concentrations and poultry house density along the streams and rivers in the Illinois River Watershed. Other technical literature has shown that *Cladophora* can be a secondary habitat for pathogenic bacteria (Byappanahalli et al., 2003; Whitman et al., 2003; Ishii et al., 2006), which greatly extends the survivability of the bacteria in the environment. When levels of TOC and DOC decrease, THM precursors and THMs levels decrease as well.

48. The U.S. EPA, the International Agency for Research on Cancer (IARC), the National Toxicology Program (NTP) and other researchers have concluded that the weight of evidence from animal and human studies warrants classification of the THMs (chloroform, bromodichloromethane, dibromochloromethane, bromoform), as well as at least two of the haloacetic acids (dichloroacetic acid, trichloroacetic acid) as Probable or Possible human carcinogens (Cantor et al., 1978; Morris et al., 1992; Nokes et al., 1999; USEPA, 2007a; Villanueva et al., 2007). One case-control study from Canada concluded that the risk of bladder cancer increased with both duration and concentration of DBP's in household water supplies (King and Marrett, 1996). In addition to the ingestion route, Villanueva et al. (2007) showed that inhalation and dermal absorption of THMs from household activities and swimming in pools may be associated with the development of cancer. A pooled analysis of six case-control studies, conducted by Villanueva et al. (1994), strengthened the conclusion that the risk of bladder cancer increases with long-term exposure to DBPs at levels that are currently observed in many

industrialized countries. In addition, a meta-analysis performed by Morris et al. (1992) concluded that there was a positive relationship between the consumption of DBP's in drinking water and bladder and rectal cancer in humans.

49. In recent years, U.S. EPA has set increasingly stringent limits on the allowable amounts of THMs in drinking water that determine what treatment facilities must achieve. In 1998, U.S. EPA issued the Stage 1 Disinfectants and Disinfection Byproducts Rule (Stage 1 DBPR), which reduced the maximum contaminant level (MCL) for THMs from 0.10 mg/L to 0.080 mg/L (100 to 80 parts per billion) and included additional compliance obligations for community water systems that chemically disinfect their water for primary or residual treatment (USEPA, 1998). Based upon results of testing following implementation of the Stage 1 rule, U.S. EPA subsequently determined that additional regulation beyond Stage I, in the form of the Stage 2 Disinfectant Byproducts Rule (Stage 2 DBPR), was needed to adequately protect human health (ADOH/DoE, 2003; USEPA, 2006c).

50. The Stage 2 DBPR places further restrictions on production and monitoring of DBPs, establishing revised Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs) for several of the DBPs. The concentration limits (MCLs) imposed by the Stage 2 DBP rule are, by definition, based upon a combination of considerations regarding health effects, technical feasibility and costs. In contrast, the development of MCLGs is based on health effects considerations only. For example, the MCLG for chloroform is 0.070 mg/L, while the MCL for total THMs, which typically are dominated by chloroform, is 0.080 mg/L. The MCLGs for two common HAA5s monochloroacetic acid and trichloroacetic acid, are 0.070 mg/L and 0.02 mg/L, respectively, while the current MCL for HAA5s is 0.060 mg/L. For the DBPs bromodichloromethane, bromoform, and dichloroacetic acid, the MCLG is zero, reflecting the ideal position that potential carcinogens should not be present in drinking water at any concentration. From a strictly health-based perspective (i.e., theoretical calculation using exposure guidelines) the following restrictive water concentrations were identified by USEPA (2006c) as being necessary to meet the standard regulatory benchmark of 1-in-one million cancer risk:

- dibromochloromethane 0.0009 mg/L
- bromodichloromethane 0.001 mg/L
- bromoform 0.008 mg/L
- dichloroacetic acid 0.0007 mg/L

In addition, the 2008 U.S. EPA Region 6 risk-based screening level for chloroform in residential water is 0.00017 mg/L (0.17 μg/L) (U.S. EPA, 2008). Wang (2007) has recently shown that water quality standards for THMs need to be reviewed to account for the different risks resulting from each individual THM species.

51. The State of Oklahoma requires that all public water systems monitor the finished water supplies for both total THMs (TTHM) and HAA5s. Available data through early-2008 from ODEQ was reviewed for the 18 currently active public water systems (Figure T2) that draw water from the Illinois River Watershed. There were 51 exceedances of the chloroform maximum contaminant level goal (MCLG) of 0.07 mg/L and 16 near exceedances (defined for purposes of this report as being within 10% of the MCLG). There were 56 exceedances of the TTHM standard of 0.08 mg/L and 29 near exceedances, and 35 exceedances of the HAA5s standard of 0.06 mg/L and 11 near exceedances. It should be noted that TTHM and HAA5s were not reported until late 2003. Prior to that time, when data for each individual component was available, TTHM values were estimated by summing these components. Currently, ODEQ has reported close to 30 violations for MCL average exceedances of either TTHM or HAA5s in tap water at customer facilities, or for sampling/reporting violations (ODEQ, 2008). There were also a multitude of exceedances of the risk-based criteria for bromodichloromethane, dibromochloromethane, and chloroform. Table T1 compares the exceedances between the risk based values and the listed MCL or MCLG values. Risk based values were exceeded over 90% of the time for both chloroform and bromodichloromethane, while the risk based value for dibromochloromethane was exceeded about 56% of the time. Stated simply, if risks of this magnitude were found at a waste disposal site or an industrial contamination site, in my experience they would require attention and remediation.

52. CDM collected water samples on three separate occasions in 2006 from 5 locations within three different IRW public water systems and analyzed them for TTHM and HAA5s. These locations are depicted in Figure T3. Of the total 45 samples collected, there were 6 exceedances and 5 near exceedances of the TTHM MCL (24%) and 3 exceedances and 1 near exceedance of the HAA5s MCL (9%). All of the samples exceeded the risk-based values for bromodichloromethane and dibromochloromethane and dichloroacetic acid, while two of the samples exceeded the individual chloroform MCLG of 0.070 mg/L. Six of the samples were greater than the MCLG of 0.02 mg/L for trichloroacetic acid. These results are illustrated in Table T2. In addition, raw water samples collected during the recreational season of 2005, 2006 and 2007 were evaluated for THM-forming potential (THMFP; CDM, 2008) and 71% of the results (57/80) showed values in excess of the TTHM MCL at twelve different locations along the Illinois River and in Lake Tenkiller. Table T3 shows the average THMFP from five PWAs. These report several of the larger systems which withdraw, treat and distribute water from the IRW.

53. Beyond the increased human health risks, elevated levels of THMs and HAA5s in drinking water often result in esthetic concerns (e.g., disagreeable taste and odors) in water supplies at concentrations which are at or near the drinking water standards (USEPA, 2006c). Thus, the water supply may be in compliance with regulatory numerical standards, but may not meet the Oklahoma narrative standards for water supplies. This general narrative criteria, found in OAC 785:45-5-9, states that "taste and odor producing substances from other than natural origin shall not interfere with the production of a potable water supply by modern treatment methods..." and "shall be maintained at all times to all surface waters of the state" (OAC, 2007). This criterion has not been met on many occasions in the IRW. In addition, the general criteria for public and private water supplies found in OAC 785:45-5-10 (5) (A) states that "The quality of the surface waters of the state which are designated as public or private water supplies shall be protected, maintained, and improved when feasible, so that the waters can be used as sources of public and private raw water supplies". In this case the water bodies in the IRW are not being adequately protected. Also found in that criterion is OAC

785:45-5-10(5) (B) which states: "These waters shall be maintained so that they will not be toxic, carcinogenic, mutagenic, or teratogenic to humans" (OAC, 2007). The reported TTHM and HAA5s concentrations detected in IRW waters clearly demonstrate that this criterion is not being met.

54. The impacts from increased disinfection byproducts (e.g., THMs and HAA5s) associated with the application of poultry waste to lands in the Illinois River Watershed represent an imminent and substantial endangerment to human health.

Cyanobacteria

55. Cyanobacteria, also often termed "harmful blue-green algae", are photosynthetic single-celled aquatic organisms that can produce potent toxins (e.g., microcystins, cylindrospermopsin, saxitoxins). It is well-documented that those toxins may be poisonous to aquatic organisms, to terrestrial animals, and to humans when present in water bodies at sufficient concentrations (Duy et al., 2000; Stewart, 2004; Falconer and Humpage, 2005; Janse et al., 2005; Health Canada, 2007; Cooke and Welch, 2008). The production of cyanobacterial toxins is influenced by a wide array of environmental conditions such as nutrient availability, light conditions, and temperature (Carson, 2000). Human health hazards occur from the following exposure routes: oral (through accidental ingestion of contaminated recreational water or ingestion of contaminated raw drinking water); dermal (through direct contact of exposed body parts with contaminated recreational waters); and inhalation (through airborne aerosols). Carmichael (2001) also reported exposure via the intravenous route in a dialysis clinic in Brazil as a result of contaminated local water supplies.

56. As ancient life forms often found living near the surface of warm water lakes and reservoirs, cyanobacteria are a well-recognized health hazard in many water supplies worldwide, including those in Europe, Australia, Asia and the Americas (WHO, 2000; Mankiewicz et al., 2005; Boaru et al., 2006; Stewart et al., 2006b). There are nearly 2,000 identified species of cyanobacteria, with more than 50 being recognized as potentially toxic to humans and animals (WHO, 2003). As noted in Chorus et al. (2000), "Cyanobacterial toxins occur naturally, but pollution with nutrients from agriculture

and domestic wastewater has led to increased fertilization (eutrophication) of many water bodies".

57. The first reported cyanobacterial poisonings were documented as animal poisoning cases, while incidences of human toxicity have been reported more recently (WHO, 2003). The effects of cyanobacteria may include low level hay fever-like symptoms, progressing to skin rashes and gastrointestinal symptoms. In addition, the toxins released by cyanobacteria can cause more specific and severe hepatic and nervous system injury (Codd, 2000; Briand et al., 2003; Stewart et al., 2006a;). The occurrence of symptoms, as well as an elevated incidence of symptoms have been described with increasing duration of water contact, as well as with increasing cyanobacterial cell counts (Pilotto et al., 1997). This risk of adverse effects is related to exposure conditions, and it has been noted that "Swimmers involuntary swallow some water while swimming; in addition, bathing suits, particularly wet suits, could accumulate cyanobacterial material and enhance the disruption of cells and the liberation of cell content" (Mankiewicz et al., 2005). In water bodies that are governed by the PBCR requirements, such as those in the IRW, the State of Oklahoma mandates that such water bodies "shall not contain chemical, physical or biological substances in concentrations that are irritating to skin or sense organs or are toxic or cause illness upon ingestion by human beings" (OAC, 2007). Toxins produced by cyanobacteria fit that prohibition, and include anatoxins and saxitoxins (nervous system), as well as microcystins, nodularins and cylindrospermopsins, which are toxic to the liver (Carmichael et al., 2001). The chances of contracting illness from cyanobacteria have been reported to increase with increasing algal bloom density and often increase toward the end of a season when cells have reached greater density and then may encounter unfavorable environmental conditions, may "lyse" (burst), and release their toxins (Dittmann and Wiegand, 2006).

58. Cyanobacterial growth is known to be enhanced by increased nutrient loading with phosphorus and other nutrient enrichment from agriculture and wastewater to surface water bodies (QWQTF, 1992; WHO, 1999; Chorus et al., 2000; Kotak et al., 2000; WHO, 2000; Briand et al., 2003; Gobler et al., 2007; Health Canada, 2007; Cooke and

Welch, 2008). Stevenson (2008) found the nutrient concentration along the streams of the Illinois River Watershed to be high and to be directly related to poultry house density in the area. Many lakes and reservoirs worldwide develop high cyanobacterial cell concentrations, especially in the warm summer months, become demonstrably greenish in color, with algal species floating to the surface under warm, still conditions, forming scums with extreme cyanobacterial cell concentrations above one million cells per milliliter ($1x10^6$ cells/mL; Falconer and Humpage, 2005). Causes of nutrient input and fertilization, mainly from phosphorus, may include insufficiently treated sewage, agricultural runoff, manure application, effluent from intensive livestock industries and runoff from roads in urban areas (QWQTF, 1992; Chorus et al., 2000; Falconer and Humpage, 2005). Eutrophication, which is the biological response to the excess of nutrients into a water body, has been identified as a major water quality management issue in a number of countries (Codd, 2000; Cooke and Welch, 2008). In addition, when turbulence of the water column is low, cyanobacteria can build up dense populations based on temperature profiles, the nutrients present, and their ability to control cell buoyancy, thereby controlling their vertical position in the water column to optimize their growth conditions (Steinberg and Hartmann, 1988; Duy et al., 2000). As noted by Falconer and Humpage (2005): "There is a strong relationship between phosphorus concentration in the water and cyanobacterial numbers and also a similar though less linked relationship between dissolved nitrate/ammonia and cyanobacteria". Managing nutrient inputs to a water body has been shown to reduce the magnitude of algal biomass, as well as reducing the frequency and duration of algal proliferation events (Biggs, 2000). Although research is limited to this point, it has been suggested that bioaccumulation of cyanobacterial toxins in food supplies may lead to adverse impacts to human health and to natural ecosystems (Duy et al., 2000).

59. When cyanobacteria become dominant in the algal community of a water body, this exacerbates negative effects on water quality based upon factors such as reduced water clarity and transparency, high primary production of algae, decreased biodiversity, and potential oxygen depletion (Mankiewicz et al., 2005). Oxygen depletion [i.e., low dissolved oxygen (DO)] can cause massive fish kills and the release

of malodorous and unpleasant tasting compounds, as well as the release of the recognized cyanobacterial toxins. Surface aggregations of cyanobacteria are possible due to their capacity to regulate their buoyancy, enabling them to localize preferentially at water depths where conditions are optimal for their growth (WHO, 2000; Dittmann and Wiegand, 2006). Visible scums of algae have been reported on the surface of Lake Tenkiller and historical data show that cyanobacteria often are the dominant phytoplankton community in the reservoir (Cooke and Welch, 2008).

60. Aside from producing toxins, cyanobacteria can be a visual nuisance and blooms often reduce water clarity, resulting in decreased recreational value of impacted lakes and reservoirs (Chorus et al., 2000; Kotak and Zurawell, 2007). The presence of cyanobacteria also can cause taste/odor problems from a number of chemicals they release, such as geosmin and methylisoborneol (Watson et al., 2003; Tung et al., 2004; Dittmann and Wiegand, 2005; Izaquirre and Taylor, 2007; Uwins et al., 2007; Juttner, 2007; Xie et al., 2007; Cooke and Welch, 2008). In addition to being free of toxic materials, according to the Oklahoma Administrative Code (OAC) 785:45-5-19 (regarding surface water supplies): "The water must also be free from noxious odors and tastes, from materials that settle to form objectional deposits, and discharges that produce undesirable effects or are a nuisance to aquatic life" (OAC, 2007). Results from a telephone survey conducted in 2006 on behalf of the state of Oklahoma, among personnel from 20 utilities along the Illinois River and Lake Tenkiller, indicated that five of the utilities (Burnt Cabin, Cherokee Co. RWD #2, Cherokee Co. RWD #13, Pettit Mountain Water, and Tenkiller Aqua Park) had received complaints of taste and odor, thus violating this Oklahoma standard. These taste and odor complaints occurred during the summer and fall months. Increases in the utilities' usage of alum, activated carbon and/or chlorine reportedly were employed to deal with this problem. Utilities with the most complaints are located in the upper reservoir, where eutrophic to hypereutrophic conditions have been shown to occur during the summer months (Cooke and Welch, 2008). Potential explanations for these negative taste and odor complaints include cyanobacterial algal products.

61. The measurement of "chlorophyll a" (Chl) concentration is used as another indicator of the abundance of algal growth (including cyanobacteria) in water bodies. Chl concentrations are used to define trophic state (or nutrient content) of water bodies and can be related to taste and odor issues. Cooke and Welch (2008) noted that the probability of cyanobacteria "blooms" rise sharply when mean summer Chl concentration is above 10 μg/L. Two sources of lake water odors that reasonably may be related to trophic state (e.g., eutrophication) have been described as high concentrations of specific algal species and bottom water odors that result from substances released from the sediment under anoxic (i.e., low oxygen) conditions (Arruda and Fromm, 1989). Existing regulations [OAC 785:45-5-10 (7)] describe the numerical criterion for Chl as "The long term average concentration of chlorophyll-a at a depth of 0.5 meters below the surface shall not exceed 0.010 milligrams per liter" in Lake Tenkiller (OAC, 2007). In this instance, "long-term average" is defined as the "arithmetic mean of at least 10 samples taken across at least 12 months" (OAC, 2007). Results from CDM sampling, as shown in Table C1, at four locations on Lake Tenkiller show that this long-term average criterion was exceeded during 2005-2006 at two of the four locations sampled with the long-term averages of 15.9 and 27.1 μg/L at LK-03 and LK-04, respectively (CDM, 2008). The other two locations, LK-01 and LK-02, had long-term average values of 6.4 and 8.7 μg/L, respectively. Although there were not enough samples to calculate long-term averages from the acquired Oklahoma Water Resources Board (OWRB) Chl data, calculated averages from 1999 through 2006 (between 10 and 15 samples at each site) at 7 locations on Lake Tenkiller show levels above 10 μg/L Chl at four of the locations (OWRB, 2006). These seven locations are illustrated in Figure C1.

62. WHO (1999) guidelines are widely used in the public health community to evaluate potential risks that may be posed by cyanobaceria in water supplies. Those guidelines state that at a density less than 20,000 cells/ mL of cyanobacteria there exists relatively low risk of adverse human health effects, while at or above 100,000 cells/mL there is moderate risk and, when visible scum of cyanobacteria is present, there is high risk of adverse health effects. Pilotto (1997) has suggested that these guidelines, while

they are commonly employed, may not in and of themselves be adequate to protect human health.

63. Results from sampling by CDM (2006, 2007) and OWRB and U.S. Army Corps of Engineers (ACoE; 2004, 2005) from several different locations (Figure C1 and C2) on Lake Tenkiller during August 2004 through August 2007 showed that approximately 58% of all samples (233/404) exhibited cyanobacterial densities of greater than 20,000 cells/mL. In addition, as listed in Table C2, approximately 24% (55/233) of those samples that were greater than 20,000 cells/ml exceeded 100,000 cells/mL (moderate risk), and one June 2006 sample exceeded 1,000,000 cells/mL.

64. Cell sizes of the cyanobacteria can vary considerably within and between species, therefore cell numbers alone may not be the only or the ideal measure of population size or potential toxicity risk (WHO, 1999). It is possible for biological volume of cells ("biovolume") to be estimated from cell counts and average cell volumes, and the resultant converted data reported as micrometers cubed per milliliter of water (μm^3/mL). However, no federal or state standards currently are available for comparison with measured biovolume values. When compared to measuring cyanobacterial genotypes, Janse et al. (2005) found that the monitoring of algal biomass/biovolume can be an adequate predictor of toxin production. The ACoE collected samples during the period from 2001 through 2004 from four different locations along Lake Tenkiller (Figure C2), and reported cyanobacteria in units of biovolume. These results are shown in Table C3 and show biovolume levels ranging from 1,800 to 60,802,075,714 μm^3/mL (over 60 billion μm^3/mL). Of the 128 total samples, 64% were greater than 1,000,000 μm^3/mL, 28% were greater than 100,000,000 μm^3/mL, and 20% were greater than 1,000,000,000 μm^3/mL. Cyanobacteria biovolume ranges for all of the CDM and OWRB samples that were greater than 20,000 cells/mL ranged from 22,000 μm^3/mL to 13,000,000 μm^3/mL. Thus, despite the absence at present of a rigorous biovolume standard, these results clearly represent potentially harmful amounts of cyanobacterial algal growth along Lake Tenkiller over four consecutive seasons.

65. The demonstrated increases in algal growth in parts of the Illinois River Watershed and Lake Tenkiller represent an imminent and substantial endangerment to human health.

Statement of Opinions

66. Based on the information presented in this report, coupled with my professional training and experience, I have the following opinions:

- There are ongoing and widespread conditions of bacterial contamination elevated over a large proportion of the Illinois River Watershed, including those areas where common uses of the Illinois River and its tributaries include aquatic recreation. The magnitude and the distribution of the elevated bacterial contamination represent imminent and substantial endangerments to human health. Several lines of evidence support the conclusion that these elevated levels of bacteria are primarily attributable to the land disposal of poultry waste.

- Increases in nutrients (e.g., phosphorus) related to the land disposal of poultry waste have resulted in eutrophication and increased algal growth broadly in the Illinois River Watershed, including Lake Tenkiller. These increased levels of algae and other forms of waterborne organic carbon combine with the normal drinking water disinfection process to produce potentially dangerous Disinfection Byproducts, such as trihalomethanes (THMs) and haloacetic acids (HAA5s). Routine and specific sampling results have identified levels of THMs and HAA5s in drinking water distribution systems that withdraw water from the Illinois River Watershed, and these levels represent an imminent and substantial endangerment to human health.

- Increases in nutrients (e.g., phosphorus) related to the land disposal of poultry waste have resulted in eutrophication and increased algal growth broadly in the Illinois River Watershed, including Lake Tenkiller. Among the measures of increased eutrophication is the detection of potentially dangerous levels of Cyanobacteria, also termed "Harmful Blue Green Algae". The levels of Cyanobacteria reported in a number of studies conducted within Lake Tenkiller represent an imminent and substantial endangerment to human health.

- There are biological and chemical hazards and impairments (i.e., bacteria and indicator organisms, THMs/HAA5s, cyanobacteria) within the Illinois River Watershed which are present at levels that are capable of causing damage to human health and which will continue to do so unless action is taken to eliminate the sources or major contributing factors for each of these hazards and impairments. The process of applying poultry waste to fields is a significant contributor to the development and persistence of these hazards and impairments of the IRW. The hazards and impairments represent an imminent and substantial endangerment to human health.

67. I reserve the right to modify and supplement the opinions presented in this report, to the extent that I become aware of new information, if reinterpretation of existing information occurs, or if it is appropriate to provide response and/or rebuttal to the technical opinions of other experts in this matter.

68. Compensation for all of my professional activities in this matter is at a rate of $195 per hour.

69. A list of the technical references that are cited herein is included as Attachment A to this report.

70. A complete copy of my Curriculum Vitae is included as Attachment B to this report.

71. A list of sworn testimony that I have provided in deposition or at trial for the period from May 15, 2004 through May 15, 2008 is presented as Attachment C to this report.

Christopher M. Teaf

CHRISTOPHER M. TEAF, Ph.D.
Toxicologist and Risk Assessment Specialist

14 May 2008
DATE